CHAPTER 2

OVERVIEW OF E911 WIRELESS TECHNOLOGY

INTRODUCTION

This chapter examines the types of 911 service, the current technology to deliver wireline and wireless 911 service, the technical issues and current technical solutions for providing wireless E911, and future technical changes that could impact wireless E911. The chapter is divided into the following sections:

A. What is 911?
B. Types of 911 Service
C. Current Wireline and Wireless 911 Service
D. E911 Service for Wireless Telecommunications
E. Technical Solutions for Phase I and Phase II
F. Upgrades to the Telecommunications Infrastructure
G. Findings

Data sources for this chapter include technical information provided by the technical workgroup convened by the Department of Revenue for this study. The following organizations participated in the technical workgroup: AirTouch Communications, AT&T Wireless Services, GTE Wireless, Nextel, GTE Network Services, US WEST, Integrated Data Communications (IDC), SCC, TruePosition, XYPOINT, King County E911, Snohomish County E911, Washington State Patrol, State E911 Office, the Washington Utilities and Transportation Commission, and the Washington State Department of Revenue.

A. WHAT IS 911?

To the public, 911 is the emergency telephone number they dial for fire, medical, and/or police emergency assistance. Callers use both wireline and wireless phones to access 911 service.

Technically, 911 is an emergency answering service. When the caller dials the digits 9-1-1 the call travels over the public telephone network to the telecommunications company's switch. The switch recognizes the 911 digits and sends the call to a 911 answering center, commonly known as a Public Safety Answering Point (PSAP).

B. TYPES OF 911 SERVICE

There are two types of 911 service--basic and enhanced. With Basic 911 service, all 911 calls go to the same PSAP in a particular area even if the caller does not live in the area served by the PSAP. When the call taker answers the call, only the voice of the caller is provided. Therefore, the call taker must request the address information from the caller, and then determine which police, fire, and emergency medical agencies need to respond to the caller's address. In addition, if the caller is unable to speak due to a medical circumstance such as a heart attack or choking, or does not know their phone number or location, the call taker may not be able to provide assistance to the caller.

With E911, the telephone company switch routes the 911 call to the PSAP that serves the address of the call. The telephone subscriber's name (this could also be a business name), address, telephone number, and associated emergency response information is sent to a computer display at the call taker answering position at the PSAP. The call taker has the information needed to send help to people who are unable to speak or do not know their telephone number or location. The display of the caller's phone number is known as Automatic Number Identification (ANI). The display of the caller's address is known as Automatic Location Identification (ALI).

By December 31,1998 all wireline subscribers in Washington State are scheduled to have Enhanced 911 service (ANI and ALI). Currently, some wireless carriers provide ANI service for their subscribers in King, Pierce, Snohomish, Clark, Thurston and Spokane counties. With ANI service the cell phone number of the caller is sent to the PSAP when they dial 911, allowing the call taker to call them back if they are disconnected. For other wireless subscribers, 911 calls are delivered to the PSAP without the caller's cell phone number.

C. CURRENT WIRELINE AND WIRELESS 911 SERVICE

Wireline 911 calls travel via the wireline E911 system from the caller to the PSAP. Wireless 911 calls travel via the wireless network to the wireline E911 system and then to the PSAP. The major components of the E911 wireline system are:

The Public Switched Telephone Network (PSTN). This is the wireline network of equipment, lines and controls assembled to establish communications paths between calling and called parties in North America.[1]

The wireless telecommunications network consists of the radio frequencies, cell sites, equipment and controls that are assembled to transport a wireless call from a wireless phone to the PSTN.

The dedicated E911 system consists of network, database, and the specialized E911 equipment at the PSAP that is required to display the E911 caller's phone number and location. This system includes telephone trunks that are used only for 911 calls.[2]

The E911 selective router is a piece of equipment located at the wireline telephone company's regional switch.[3] The selective router sends the E911 call to the proper PSAP based on the telephone number of the calling party, the location of the caller, and a routing code called an emergency service number (ESN).[4] It controls delivery of the voice call with ANI to the PSAP and provides Selective Routing, Speed Calling, Selective Transfer, Fixed Transfer and certain maintenance functions for each PSAP.

The E911 database is a database which houses the ANI and ALI records of telephone subscribers. The information includes a database of street names and house number ranges, and the telephone customer's names, addresses, phone numbers and emergency response information. The 911 database is maintained by the telephone company.

The 911 call answering points, known as Public Safety Answering Points PSAPs, are facilities that are equipped and staffed to handle 911 calls 24 hours a day, seven days a week. A primary PSAP receives the calls directly. A secondary PSAP only receives calls that have been transferred to them by the primary PSAP.[5]

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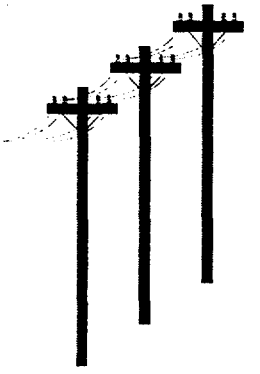
[1] US WEST and GTE networks have been upgraded to include 911 selective routers and a 911 database. The other local exchange companies, competitive local exchange companies, and the wireless companies interconnect with the US WEST and GTE 911 systems to complete their subscriber's 911 calls to the PSAPs.

[2] A trunk is a communication path between wireline central office switches, or between the 911 Control Office and the PSAP.

[3] The wireline company's regional switch, commonly known as the tandem switch, manages the calls from one or more counties. For example, US WEST has a regional switch in Spokane that manages calls for 11 counties.

[4] The ESN is a number representing emergency services agencies (Law Enforcement, Fire, and Emergency Medical Service) that serve a specific range of addresses within a particular geographic area known as an Emergency Service Zone (ESZ). The ESN facilitates selective routing to the appropriate PSAP and the dispatching of the proper service agency(ies).

[5] There are 80 PSAPs in Washington State to answer 911 calls—65 primary PSAPs and 15 secondary PSAPs. The primary PSAPs initially answer 911 calls or seven digit emergency numbers. Secondary PSAPs only answer transferred calls. Counties operate 72 PSAPs and the Washington State Patrol (WSP) operates eight. WSP has five PSAPs that are primarily used for answering wireless 911 calls. The other three PSAPs answer calls transferred from local jurisdictions



How does Wireline Enhanced 911 Service Work?

When a caller dials 9-1-1 from a wireline phone, the call travels over the PSTN just like any other call to the telephone company's central office (CO).[6] At the CO, the switching equipment recognizes the digits 9-1-1 and immediately transfers the call from the public switched network to dedicated 911 trunks that carry the call to the 911 selective router. At the 911 selective router, specialized software recognizes the 911 routing number associated with the caller's telephone number and routes the call along dedicated 911 trunks to the PSAP that serves the caller's geographic area. When the 911 call is received by the specialized 911 equipment at the PSAP, the caller's phone number is automatically sent via dedicated data circuits to the 911 database, which is maintained by the telephone company providing 911 service to the PSAP. The caller's name, address, telephone number, and associated emergency response information is retrieved from the 911 database. The caller's information is sent to the PSAP over the data circuits to a display at the call taker answering position. The call taker has the information needed to send help to people who are unable to speak or do not know their telephone number or location (See Diagram 2.A).

How Does the current Wireless 911 Service Work?

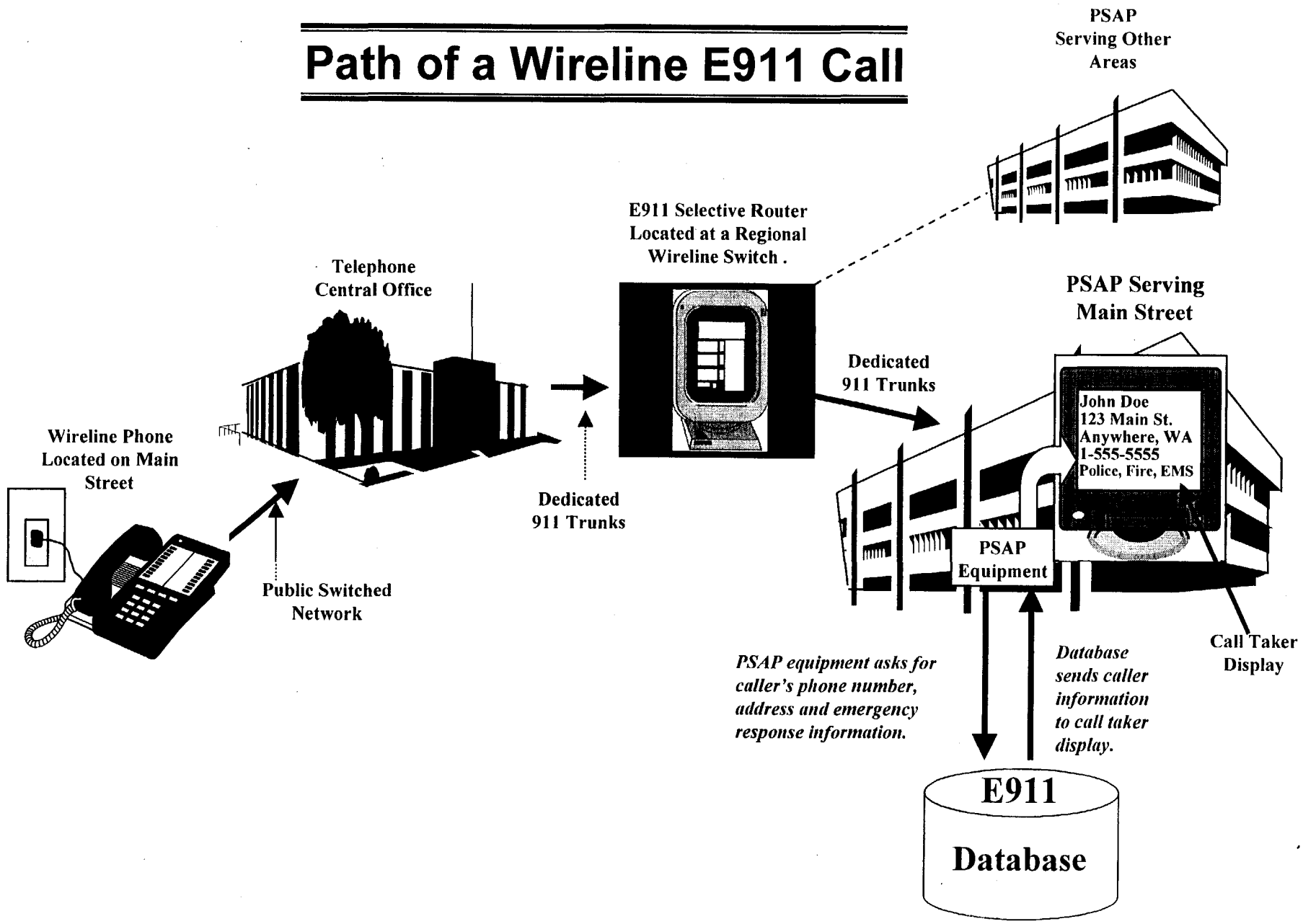
When a caller dials 911 from a wireless phone, the call travels via radio frequency to a cell site and then over telephone lines to a wireless switch. Based on the area it covers, each cell site is predetermined to route 911 calls to the PSAP which provides 911 service for the majority of the area covered by the cell site. From this point, there are a variety of methods being used to transport the 911 calls to PSAPs.

Forward the 911 Call to a Seven-Digit Number - The wireless switch recognizes the 911 digits and forwards the 911 call over the PSTN to the seven-digit number at a PSAP. There is no phone number, address, or other subscriber information provided, and the caller must be able to provide their phone number and location to the call taker at the PSAP before assistance can be provided (See Diagram 2.B).

Forward the 911 Call to a Seven-Digit 911 Trunk Number – Each 911 trunk group to the PSAP has a seven-digit telephone number associated with it. In this case, the wireless switch recognizes the 911 digits and forwards the call through the 911 selective router to the dedicated 911 trunk group that goes to the PSAP. Once again, there is no phone number, address, or other subscriber information provided (See Diagram 2.C).

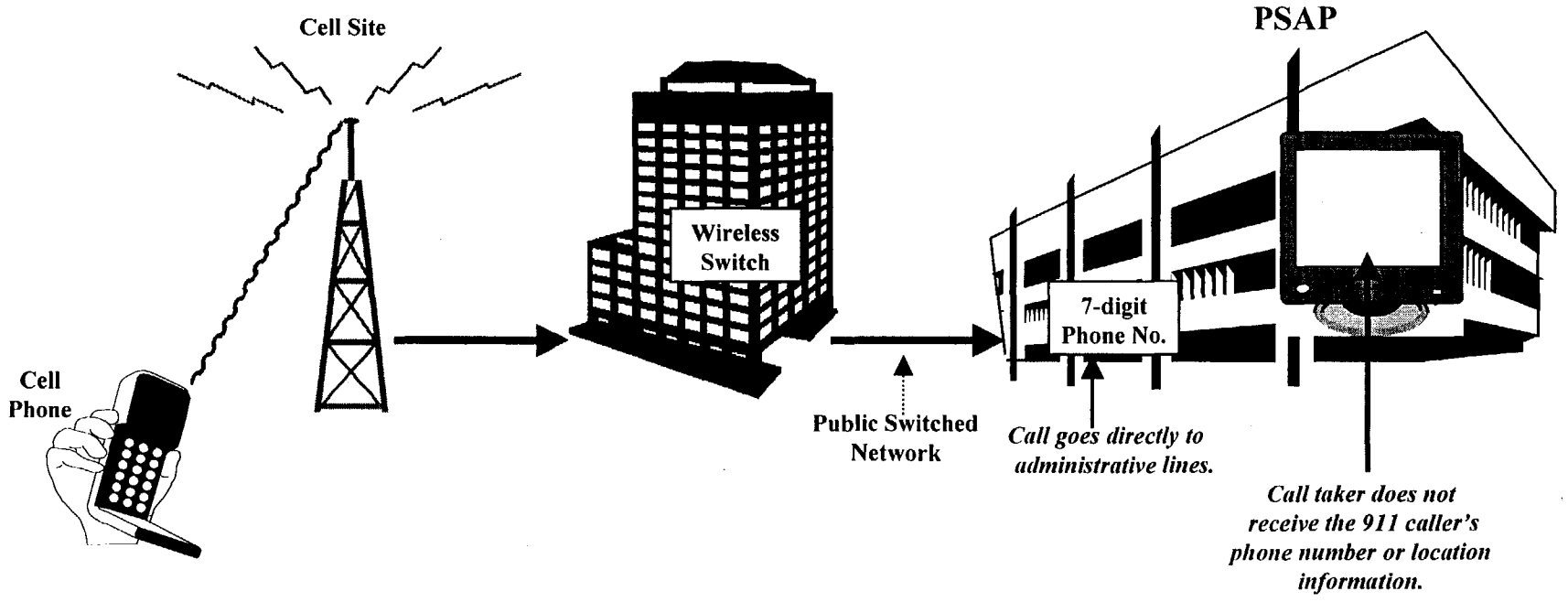
[6]The CO is the local exchange carrier facility where access lines are connected to switching equipment for connection to the Public Switched Telephone Network.

Path of a Wireline E911 Call



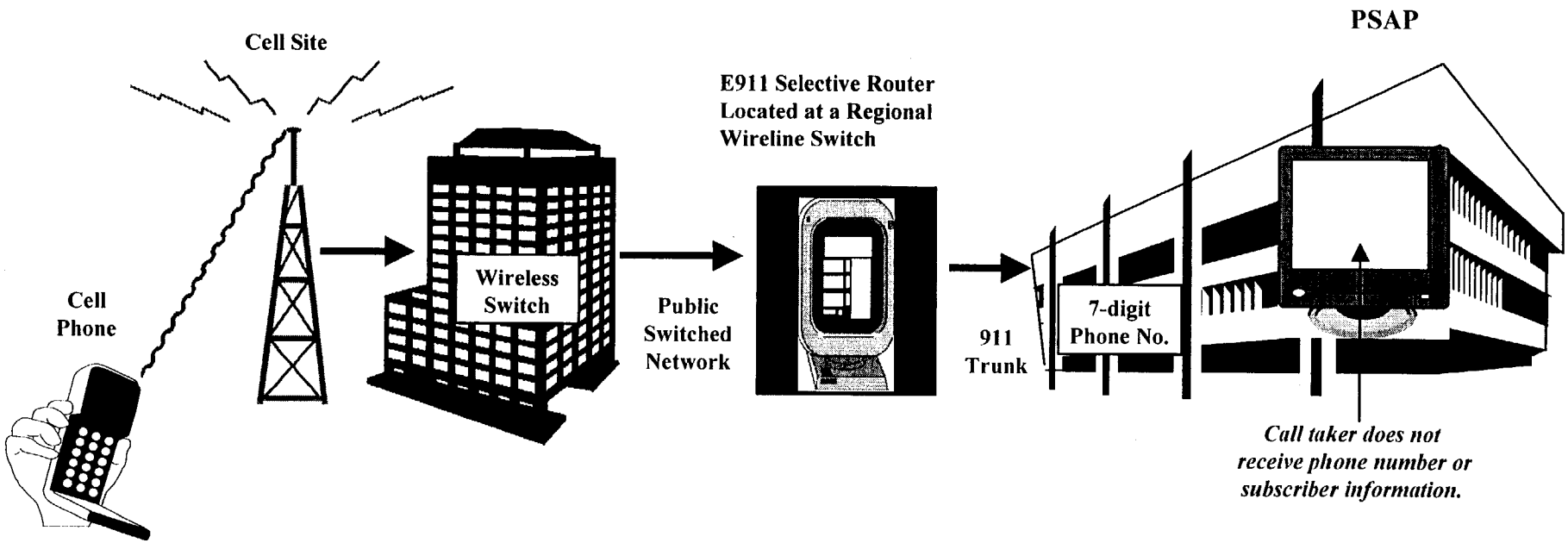
Current Wireless 911 Service

Forward the 911 Call to a 7-Digit Number at the PSAP



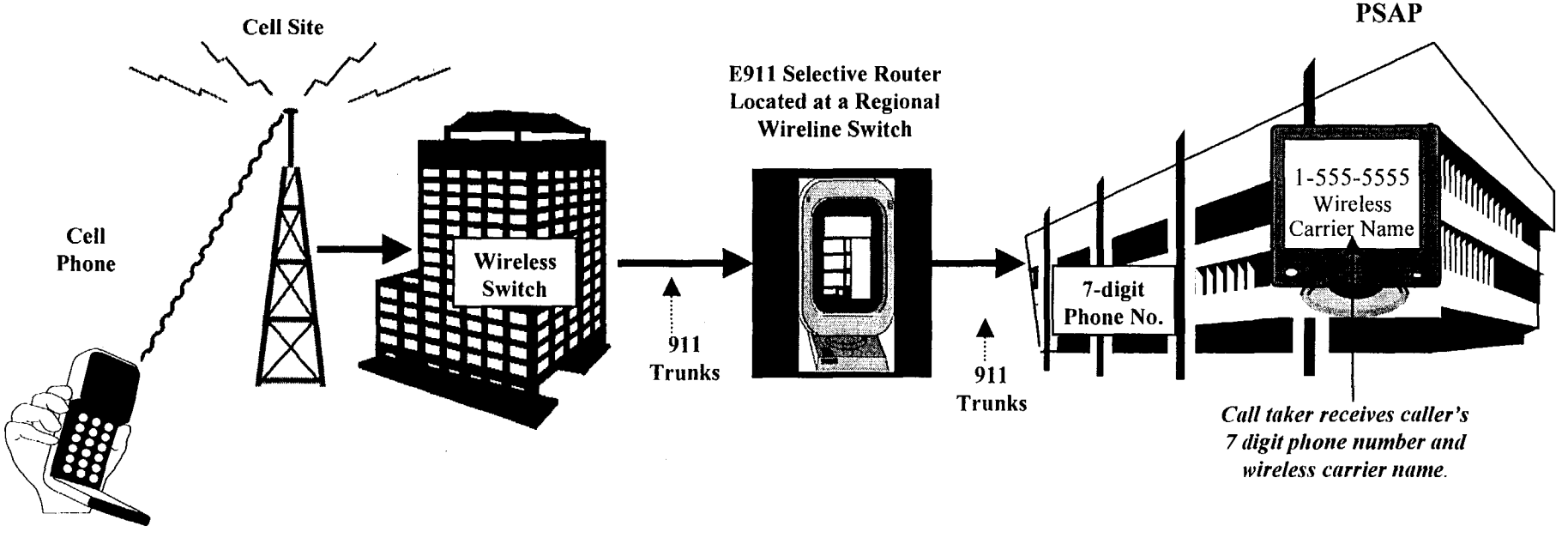
Current Wireless 911 Service

Forward the 911 Call to a 7-Digit 911 Trunk Number



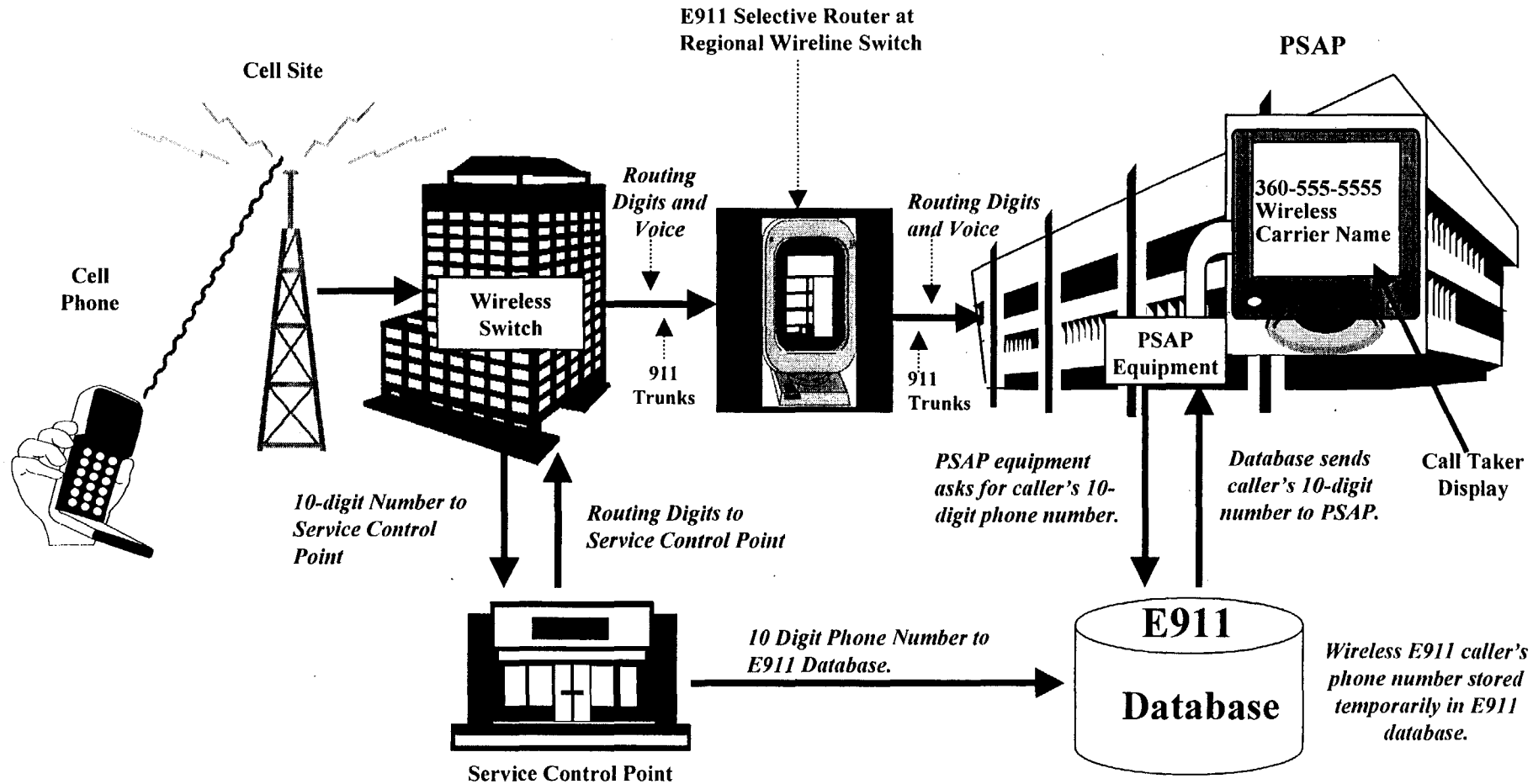
Current Wireless 911 Service

Provide 7-Digit Automatic Number Identification to the PSAP



Path of a Wireless 911 Call

Provide 10-Digit Automatic Number Identification to the PSAP



Seven-Digit ANI – Two major wireless carriers currently provide (ANI) for their subscribers in King, Pierce, Thurston, Clark, Snohomish, and Spokane counties. Dedicated 911 trunks have been installed between the wireless switch and the 911 selective router, and 911 calls are transported over these trunks to the 911 selective router and then over the existing dedicated 911 trunks to the PSAPs. This is a limited system that can only pass seven-digits, and as a result, ANI cannot be displayed for callers who are calling from outside their local service area. The name of the wireless carrier which provides service to the caller is displayed at the PSAP along with the caller's ANI. No other subscriber or address information is available (See Diagram 2.D).

Ten-Digit ANI – Two major wireless carriers have recently begun providing ten-digit ANI service for some of their subscribers in Clark County. One major carrier provides 10 digit ANI in King County. The 911 calls are sent from the MSC to the 911 selective router over a dedicated circuit, and from the selective router over existing 911 trunks to the PSAPs. The telephone companies have upgraded the 911 selective routers in order to allow the wireless companies to interconnect their networks with the 911 network. The ten-digit ANI of all 911 callers, even those outside their local calling area, along with the wireless carrier name, are provided to the PSAP. No location information is provided (See Diagram 2.E).

D. E911 Service For Wireless Telecommunications

The FCC issued an order in 1996 that requires wireless carriers to provide enhanced 911 service to their subscribers.[7] This means that wireless callers will have similar levels of ANI and ALI service for 911 calls as wireline callers currently have.

The wireless carriers are to implement wireless E911 in two phases. In Phase I, they are required to provide the 911 caller's phone number and cell sector location by April 1998 or six months after the service is ordered. The wireless carriers are working to solve the technical challenges of Phase I. The challenges include the following:

- Phase I requires 20 digits of information be sent to the PSAP. The current 911 system only accommodates 8 digits.

- The current in-band signaling is not fast enough to handle the additional digits without delaying the connection of the 911 call.[8]

- Currently, the wireless customer's phone number and cell sector location information are automatically sent to the wireless switch for billing purposes. Under Phase I, when the customer dials 911 the wireless switch has to recognize the 911 number sequence

[7] The Federal Communications Commission Docket Number 94-102 "Report and Order and Further Notice of Proposed Rule Making in the Matter of Revision of the Commission's Rules to Insure Compatibility with Enhanced 911 Emergency Calling Systems" stated June 12, 1996; published July 26, 1996.

[8] In-band signaling means that the data and the voice travel on the same path to complete the call.

and instead of billing for the call, route the call to the PSAP and the digital information to the911 database.

It will be necessary to implement Phase I prior to or simultaneously with Phase II because the Phase I technology provides networking and database management that will still be needed in Phase II. In addition, Phase I will provide a back-up system for Phase II. If the latitude and longitude information in Phase II fail, the Phase I technology will still provide cell sector location information for call routing and PSAP display purposes.

In Phase II, the wireless carriers have to provide the caller's latitude and longitude within a radius of 125 meters (410 feet) at least 67 percent of the time by October 1, 2001 or six months after the service is ordered. This means that the actual location of the caller has to be determined, the data has to be sent through the 911 system to the PSAP, and the latitude and longitude data have to be converted into a usable location so the 911 call can be dispatched. If the caller is moving, it may be desirable that the location be updated to track the caller, although this is not a requirement of the FCC order. If the caller is out of their home area, the wireless systems have to be interoperable to offer 911 service. The technical challenges of Phase II include:

Locating the wireless caller. Wireless callers are usually mobile and technology has to locate callers in terms of latitude and longitude.

Generating accurate data to describe the location. Data for latitude, longitude, altitude, speed, and direction are necessary to physically locate a moving caller. Data calculations may be skewed by physical terrain, weather, user operation (eg. indoor, in-vehicle, mobile or stationary). The time to transmit the data is affected by the call volume, geography, and user operation.

Moving the location data through the 911 network. The new data requires up to 40 digits. The current selective router and 911 network can only handle 8 digits.

Transmitting more data per caller through the system if the caller is moving. The data changes as the person moves. Data may need to be transmitted more frequently to effectively track a moving caller. This could result in conversations being interrupted if location updates use in-band signaling.

Translating digital data to a usable location. In order for call takers to communicate the actual location of a caller to dispatchers, existing maps will have to be corrected to reflect latitude and longitude and will need frequent updates to maintain accuracy. These maps will have to be electronically available at each call taker position at the PSAPs.

Interfacing with different frequency technologies and multiple infrastructure and network configurations. There are different technologies, frequencies, and network

configurations among the wireless carriers. All of these systems have to interface with the E911 network.[9]

E. TECHNICAL SOLUTIONS FOR PHASE I AND PHASE II

PHASE I

The limitation in today's wireline E911 network is the current signaling, known as the CAMA protocol. CAMA will only support a maximum of eight digits for transport through the network. The 8 digit phone number is a combination of the wireline caller's seven digit phone number with one digit added at the beginning of the phone number to indicate the area code. For example, the phone number (206) 413-1234 would be represented in the current 911 system by the following digits: 04131234. This is sufficient for wireline 911 calls but not for wireless calls which require 20 digits of information.

Another limitation in today's wireline E911 network is that the current selective routing equipment in the E911 network will only support CAMA signaling.

The incumbent telephone companies, private vendors, and wireless companies have addressed the technical problems for Phase I by developing two basic solutions. One solution sends the voice and data in the same path for delivery to the PSAP. This is called Call Path Associated Signaling (CAS). The other solution splits the voice and data and sends them in separate paths so that the voice and data still reach the PSAP at the same time. This is known as Non Call Path Associated Signaling (NCAS).

The CAS solution, which sends voice and data in the same path, requires hardware and software upgrades to existing E911 equipment. The NCAS solution, which sends the voice and data in separate paths and reunites them at the PSAP, uses the existing 911 network and does not require hardware upgrades.

HOW PHASE I TECHNOLOGIES WORK

When the wireless caller dials the digits 911, the call is transmitted to the wireless carrier's switch that is capable of determining three basic characteristics of the call. First, it recognizes the digits 911. Second, it determines the caller's 10 digit telephone number and third, the cell tower and cell sector from which the call originated.[10] The call is then processed according to the technical solution being used by the wireless carrier. Below are technical descriptions of each solution.

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[9] The American National Standards Institute (ANSI), an accredited standards body under the auspices of the Telecommunications Industry, is addressing the majority of the technical challenges in this list. The work of this standards body is applicable to cellular and PCS services but not SMR.

[10] A cell site typically has one to three cell sectors. Each cell sector is an area geographically defined by the wireless company and served by one face of a cell antenna. Most companies assign each cell sector one or more 10 digit numbers identifying the cell sector location. The assignment of these numbers depends on the solution being used by the wireless carrier—either CAS or NCAS.

Call Associated Signaling (CAS)

This solution must be provided or supported by the local wireline phone company. In this solution, 20 digits (including the caller's phone number and the 10 digit cell sector number) are transferred over a special trunk line from the wireless switch to the wireline phone company's E911 network. To support receipt of these 20 digits, the wireline phone company can either: 1) upgrade their existing selective router; or 2) add an additional piece of special equipment in front of the existing selective router.

An upgrade to the existing selective router is capable of sending 20 digits all the way through the E911 network. It allows upgraded signaling to be supported which sends voice and data in the same path. The information is sent from the selective router directly to the PSAP on E911 dedicated trunks. The voice, the caller's phone number, and the cell sector location arrive at the call taker's position at the PSAP. This solution does require upgrades to the PSAP equipment and to the signaling from the selective router to the PSAP. Both GTE and US WEST are in the process of installing new selective routers and upgrading the E911 network.

GTE is currently installing and testing four selective routers that will be installed by December 31, 1998. US WEST plans to upgrade their selective routers to handle more digits starting in 1999.[11]

The other CAS option is to add an additional piece of special equipment in front of the selective router. The special equipment has three main functions. First, it converts the 20 digits to eight digits. Second, it inserts the caller record in the form of 20 digits (10 digits for the caller's number and 10 digits for the cell sector location) into the E911 database. Third, it sends the eight digit number and the voice to the PSAP over the dedicated 911 trunks that are in place today. When the voice and the eight digit number reach the PSAP, 911 equipment recognizes the eight digit number and queries the E911 database. The E911 database converts the eight digit number that is sent from the PSAP into the original 10 digit cell sector number. Then it retrieves the caller's record that was inserted into the E911 database by matching the original and the converted 10 digit cell sector numbers (See Diagram 2.F).

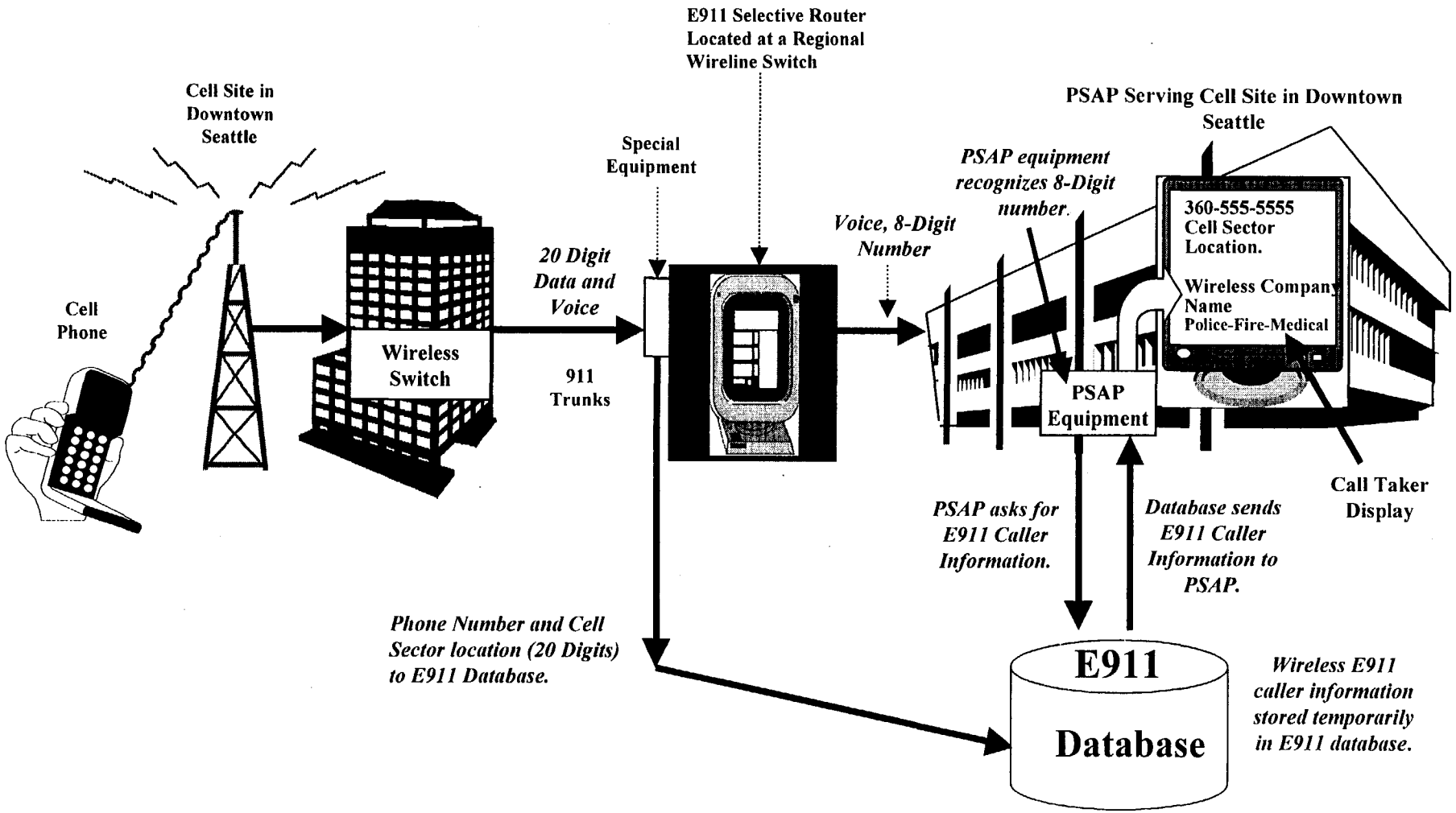
Non-Call Path Associated Signaling (NCAS)

The wireless carriers typically contract with private vendors to provide the NCAS solution. With the NCAS solution the voice and data are separated at the wireless carrier's switch. The wireless switch forwards the caller's phone number and 10 digit cell sector number through a Signaling System 7 (SS7) network to a sophisticated computer, called the service control point (SCP). Based on the address of the cell site where the call originated, SCP's database assigns an eight digit number. The eight digits serve as routing digits that deliver the call to the most appropriate PSAP. The routing digits are then sent from the service control point back to the wireless switch where they are joined with the caller's voice and forwarded to the

[11] The new selective routers require upgrades to the ALI database systems in order to handle the dynamic record updates delivered by the selective router at the time of the E911 call.

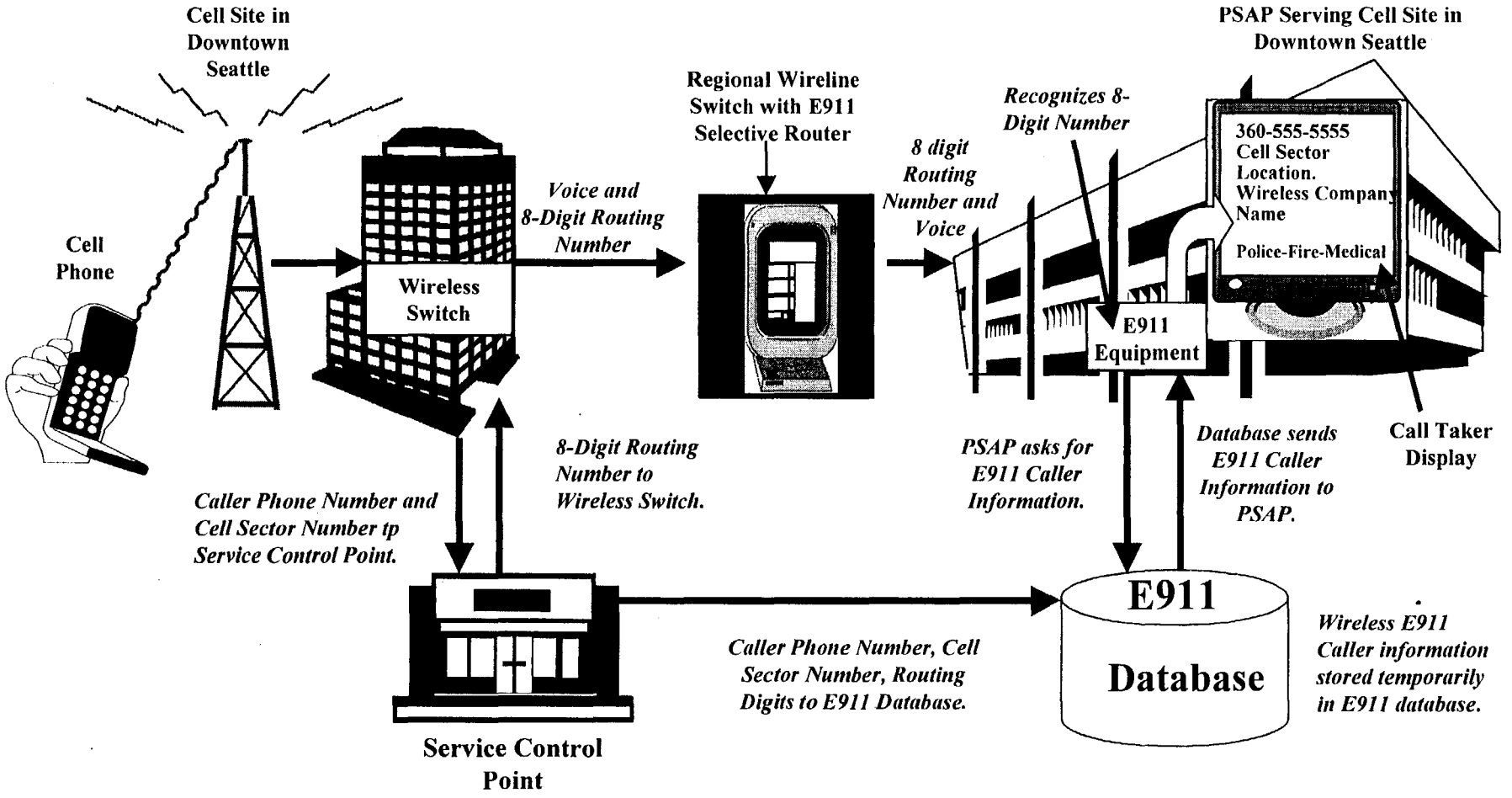
Phase1

Call Associated Signaling



Phase1

Non-Call Path Associated Signaling



wireline E911 network. The digits used for routing have been pre-provisioned to facilitate routing through the existing selective router to the appropriate PSAP. Meanwhile, the service control point updates the E911 database with caller's phone number, cell sector location information, and routing digits. When the voice and the routing digits reach the PSAP, the 911 equipment queries the E911 database. The caller's information is retrieved from the E911 database by matching the routing digits. The voice, the caller's phone number and cell sector location then arrive at the callers taker's position in the PSAP (See Diagram 2.G).

PHASE II

Private research and development companies are currently developing and testing cellular network solutions and handset-based solutions to Phase II. With the cellular network solutions, location technology is added to the current cell sites to calculate a caller's latitude and longitude. The technology works as long as the caller's phone can access at least two cell sites. With the handset based solutions, latitude and longitude data from satellites orbiting the earth is received by a chip in the handset and sent to the PSAP.[12] This technology works as long as the handset can receive the satellite signal. Some handset technologies process the information in the handset and send the data through to the PSAP. Other technologies receive the raw location data in the handset and send the data to a central location for processing. The location data is then sent to the PSAP. Some of the cellular network solutions are already in deployment.[13] The handset-based solutions are in the testing phase.[14]

HOW CELLULAR NETWORK SOLUTIONS WORK

Cellular network solutions add location technology to the cell sites and calculate the location information using triangulation methods. When the caller dials 911, the signal is picked up by two or more cell sites. Computer software analyzes data from the cell sites using a particular method or a hybrid of the following methods—time difference of arrival (TDOA) and angle of arrival (AOA).

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[12] The United States Department of Defense has a system of 24 satellites that orbit the earth and continually send out location data. The raw data can be picked up by receivers and translated into location information. This system is called the Global Positioning System (GPS).

[13] TruePosition has operated field trials for a Cellular Network Solution along a 350 square mile area on Interstate 95 in New Jersey and in metropolitan Houston, Texas. Subsequent to these field trials the technology is in commercial rollout in the greater Philadelphia area including parts of Pennsylvania, Delaware, and New Jersey as well as in Greater Harris County encompassing Houston, Texas.

[14] A test on the handset solution is being conducted in King County, Washington by Integrated Data Communications (IDC) of Seattle. IDC has a patent on technology that allows GPS data to be processed by a chip in the wireless handset and then sent to the PSAP. The King County test has three phases. The first stage of the evaluation began in June 1998 and tests the locating ability of GPS receivers in a wide variety of locations including mountains, freeways, tunnels, buildings, urban canyons, etc. The second stage of the evaluation will demonstrate the ability to route wireless calls to the correct PSAP based on location information provided by the handset. These tests began the second week of July 1998. The third stage will test the end to end capability of the system. Three PSAPs have been equipped with IDC equipment to work with GPS enabled handsets. The final tests were completed August 14, 1998 and the final report will be available mid-September 1998. IDC's partners in the test are: King County, Washington; U S WEST; Network Design Engineering (NDE); CML; Valor; SCC; Positron; Network Orange; WR Inc.; AirTouch Cellular.

Time Difference Of Arrival **(TDOA)** uses data from three or more cell sites and the time of arrival to compute where the caller is located. The TDOA system is an overlay system that fits on the existing network so there is little impact to the wireless network. Because the system relies exclusively on the radio signals that are broadcast from the phone to locate a caller, the location quality of the system generally follows the voice quality of the underlying cellular network. As a wireless carrier expands and improves coverage in their network, the location system quality similarly expands. For a TDOA system, the location accuracy for indoor coverage deteriorates as the quality of the wireless call deteriorates. If the indoor cellular phone has good voice reception and transmission quality, then the location accuracy is relatively unaffected.

The advantages to this method are that it can be applied to different wireless technologies and no modification to the handset is required. Once the system is installed all wireless subscribers would have automatic location identification within 410 feet 67 percent of the time as long as their wireless phone signal could access a cell site.[15]

The challenges with TDOA are that it is dependent on the cell site configuration such as exact cell location, antenna height, and radio channel allocations. Therefore cooperation with existing wireless carriers is needed. It is also dependent on the number of radio location receiver sites. The quality of accuracy of a TDOA system is proportional to the coverage area of TDOA radio location receiver sites. An urban core typically requires one TDOA receiver site for every three or four cell sites. A rural area, with much larger cell coverage patterns, would typically require one TDOA receiver per cell site. The performance is affected when the radio signal bounces off objects along the path from the radio transmitter such as hills and buildings (This is known as multipath).[16] The quality of the indoor coverage varies with the strength of the signal. TDOA requires accurate network time synchronization and an extensive cell site overlay (See Diagram 2.H).

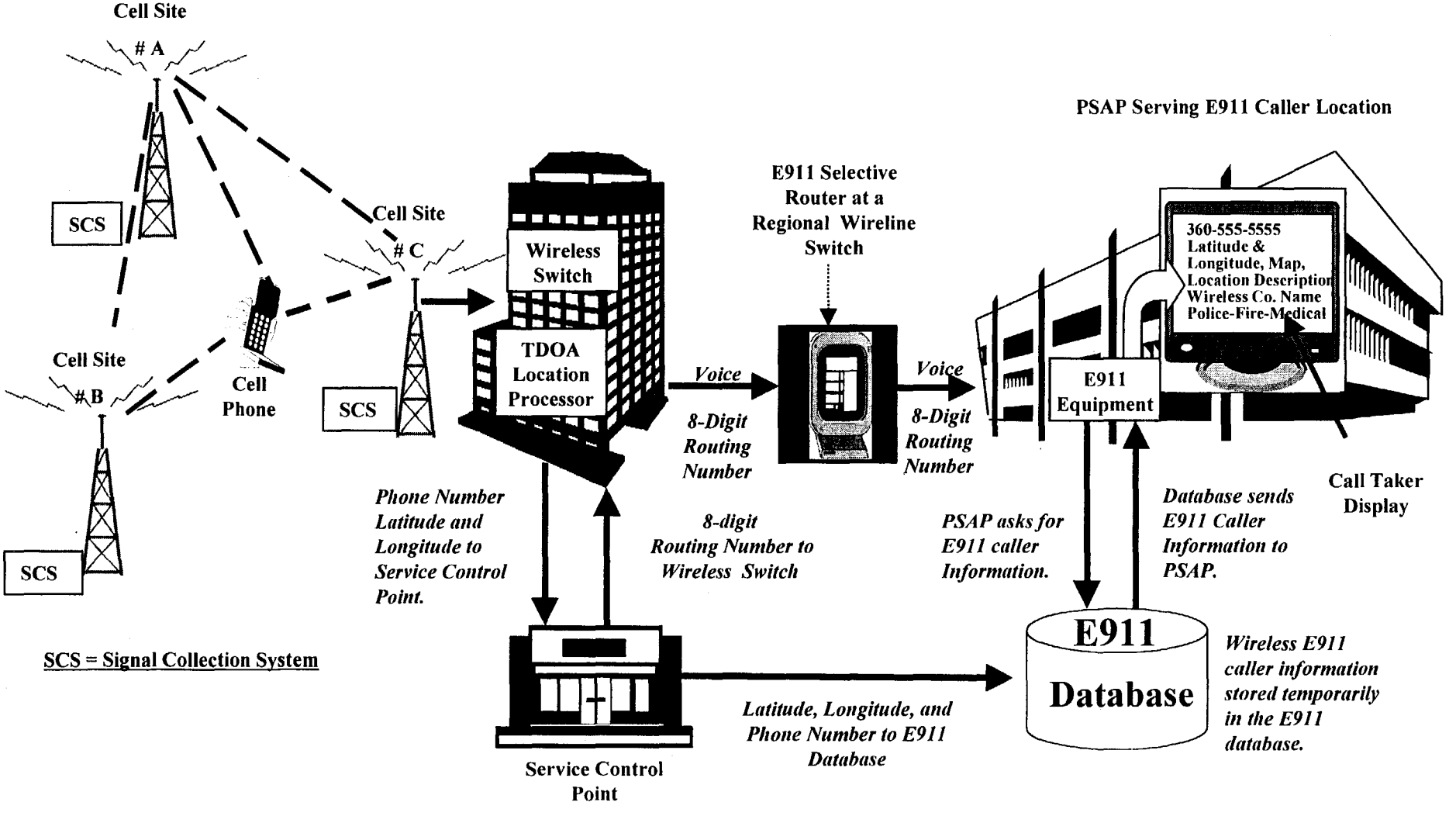
Angle of Arrival **(AOA)** uses data from two or more cell sites and the angle of arrival to compute where a caller is located. The advantages to this method are that it applies to all mobile phones of any make, model, and vintage with no modifications to the handset required. The AOA system is an overlay system that fits on the existing network so there is little impact to the wireless network. Because the system relies exclusively on the radio signals that are broadcast from the phone to locate a caller, the location quality of the system generally follows the voice quality of the underlying cellular network. Similar to TDOA, the AOA system requires a series of angular location sites to be deployed in the network. There are fewer AOA sites needed in an urban core per cell than in a rural area. An asset of AOA is its resistance to multipath effects which includes good indoor coverage. The challenges with this system are that it is typically dependent on additional antenna structures at the cell site.

[15] Automatic location identification for TDOA includes latitude and longitude but not altitude.

[16] When the radio signal bounces off objects along the path from the radio transmitter to the receiver, such as buildings or hills, it is known as multipath. The result is that the radio signal received at the transmitter is not made up of a "pure" direct transmission but instead includes several weaker bounced signals that each have slightly different timing and phase characteristics than the direct transmission. These reflected signals will vary in timing and in the level and quality of the directly transmitted signal. This is analogous to hearing a voice echo in a marble hallway.

Phase II

Cellular Network Solution
Time Difference of Arrival (TDOA)



2. H

Therefore cooperation with the existing wireless operators is needed for access to most structures. The accuracy of an AOA system is inversely proportional to the distance of the phone from the AOA sites (the further the phone is away, the less accurate the system). Also, in rural configurations, cell sites tend to be adjacent to highways. This is a poor configuration for AOA since no location can be detected along the line-of-sight between two AOA receivers.

How Handset Solutions Work

Currently there are two handset solutions being tested. Both use Global Positioning Satellite (GPS) technology to obtain location information. The advantage of a GPS solution is its inherent high accuracy (as close as 40 feet in tests conducted in King County, Washington). Some of the challenges with this technology will be its use in skyscrapers where it is difficult for the handset to receive the GPS data.[17] The handset solution needs to be accepted as a national solution or handsets of subscribers from different areas will not be compatible. There is also the issue of what to do about the handsets that are currently in use. One solution is to offer an after market battery pack adapter that allows the addition of the GPS receiver to the battery pack. Since there is a fairly fast turnover in handsets it would not be too long before a large number of users would have the GPS technology built into the handset. Two major handset manufacturers have announced that they will be building GPS technology into handsets in the near future.[18]

Cellular-Assisted GPS Handset Solution

The cellular-assisted GPS uses a GPS receiver in the handset to collect raw data from the satellites. The raw data is then sent to equipment located at cell sites and then forwarded to network equipment for further processing. This network equipment computes and sends the latitude, longitude, and other location information to other network equipment for transmission to the PSAP. The advantage of the cellular-assisted GPS is that it reduces the processing of satellite data in the handset by using high-speed network-based computing. An additional advantage is that error correction and the time to get an initial reading are improved by the ability of the network to send information to the handset (See Diagram 2.I).

Autonomous GPS Handset Solution

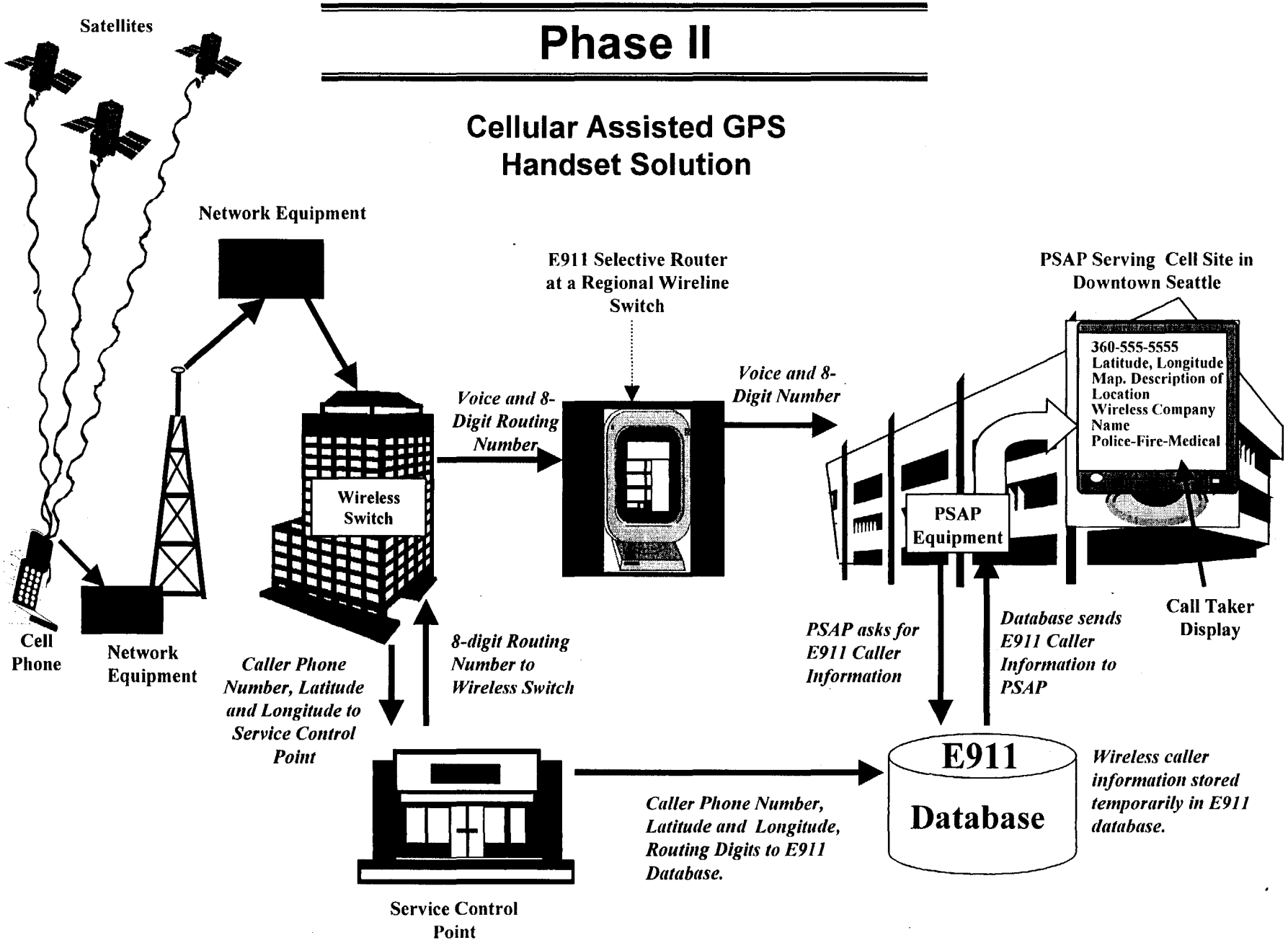
The autonomous GPS handset uses a complete GPS receiver and processor located in the handset. This stand-alone device does not need any network connections to obtain location information. The on-board processor can send location information through the cellular network overhead data channels or over the voice path via in-band technology. The advantage of sending the data via the voice path is that location information can be sent over

[17] Tall buildings can be retrofitted to receive GPS information. Antennae are placed on the roof and at each floor to send the signal to a GPS receiver inside the building.

[18] Nokia and Ericsson have announced that they will be including a GPS chip in their newest handset models.

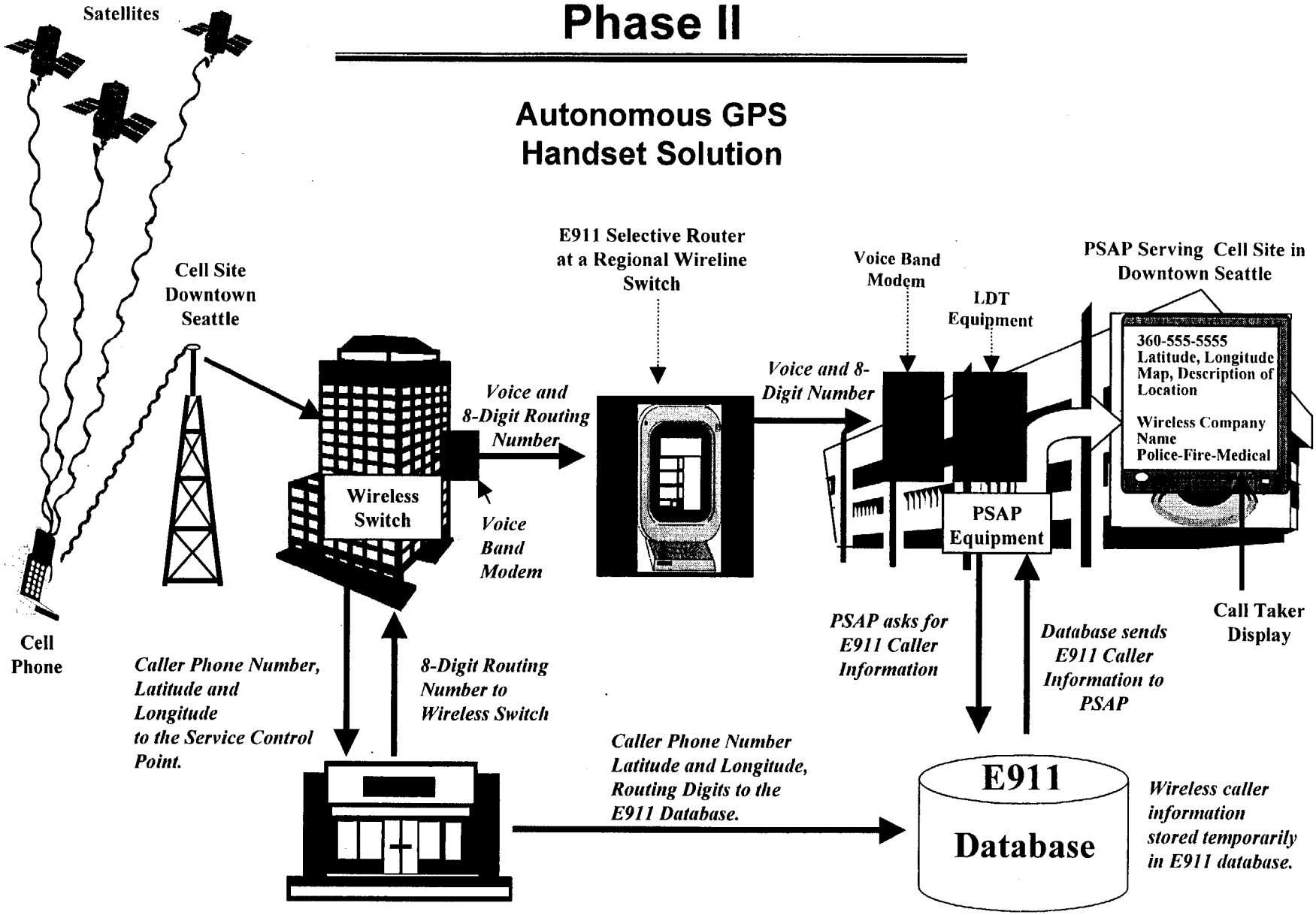
Phase II

Cellular Assisted GPS Handset Solution



Phase II

Autonomous GPS Handset Solution



any cellular or wireline network directly to the PSAP without changing any of the existing network (See Diagram 2.J).

TECHNICAL IMPLEMENTATION OF PHASE I AND PHASE II

Some stakeholders have questioned whether it is technically possible to skip Phase I and move directly into Phase II. It is not really possible to "skip" Phase I because each phase upgrades a different part of the network. Phase I upgrades the network from the MSC to the router to the PSAP. Phase II upgrades the network from the cell site to the MSC. Technically Phase I is imbedded in Phase II. If the latitude and longitude information fail in Phase II, the 911 system will still provide cell sector location from the Phase I technology. Phase I and Phase II can be implemented simultaneously or in sequence but both have to be implemented to have a wireless E911 system with a backup system in place.

F. UPGRADES TO THE TELECOMMUNICATIONS INFRASTRUCTURE

The E911 network is being upgraded to process additional digital information that will result from multiple area codes, number portability, and wireless E911. The impacts of the upgrade on the 911 system are significant. Selective routers will be able to communicate with each other and send calls from switch to switch. Currently PSAPs served by a different selective router have to send a call from one PSAP to another via a seven-digit number. These upgrades will streamline the call delivery process.

CHAPTER 3

TECHNICAL COMPONENTS FOR WIRELINE AND WIRELESS E911 SERVICE

INTRODUCTION

Chapter 3 examines the network, technology, equipment, and facilities that were added to the wireline telephone system and the PSAPs to build the current E911 network in Washington State.[1] The chapter explains the new and upgraded network, technology, equipment, and facilities that have to be added to the E911 network to implement Phase I and Phase II service. The chapter consists of the following sections:

A. What is a Technical Component?
B. Technical Components for the Current E911 Network
C. Technical Components For Phase I
D. Projected Technical Components For Phase II

A. WHAT IS A TECHNICAL COMPONENT?

For purposes of this report, a technical component is "a unique, identified part of the E911 system that is necessary to deliver the 911 call and associated information from the caller's telephone to the PSAP."[2]

The technical workgroup defined the term "technical component" to identify the basic components that comprise the current E911 network and the additional components needed to implement wireless E911 service. The definition also provides a technical unit of comparison for the wireline and wireless companies, the vendors, and the PSAPs. They work together to implement wireless E911 service and have diverse technology, networks, equipment, and facilities that cannot be easily compared at a micro level.

Chart A lists the projected technical components for wireline and wireless E911 service. It also illustrates at what stage in Phase I or Phase II service that the wireline and wireless carriers, vendors and PSAPs may require new or additional technical components. The chart identifies the technical component by an "X" if it is part of the current E911 network, an "N"

[1] In 1985, the large urban counties in Washington State began to implement wireline E911 service. In 1991, the voters passed Referendum 42 that mandated all the counties to expand E911 service statewide by 1998. Since 1992, the smaller counties, with the assistance of the State E911 Office, have worked to meet the mandate.
[2] This definition was composed by the technical work group.

Chart 3. A

Technical Components for the Current E911 Network, Phase I and Phase II

Technical Components (TC)	*Dedicated 911 trunks from Central Office to Selective Router	*Dedicated 911 trunking from selective router to PSAP	911 Selective Routing (Wireline)	E911 Database (add space for wireless)	Database Administration	Data circuits to existing E911 database	PSAP controller (add capacity)	ALI modem (upgrade for speed)	Telephone System/ TDD Terminals	ANI display (new hardware and software)	ALI display (new hardware and software)	CAD system	Administration	ALI steering interface	Dedicated trunks from MSC to selective router	Dedicated facilities from MSC to selective router	Software features (MSC)	Routing Translation (Wireless)	Data links to private vendor (SS7 or other signaling)	Service Control Point (SCP)	Relational PSAP Database	Mapping	Location Determination Tech. data extraction equipment	Voice band modem to control GPS receiver (for advanced GPS handset	GPS enabled handset	Position determining Equipment (per cell site 1:2)	TDOA location processor at MSC
TC Numbers	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Wireline																											
Wire E911	X	X	X	X	X	X							X														
Phase 1			**A**	**A**	**A**	**A**							**A**	**N**													
Phase 2			**A**	**A**	**A**	**A**							**A**														
PSAP																											
Wire E911**					X	X	X	X	X	X	X	X	X														
Phase 1					**A**								**A**														
Phase 2					**A**		**A**	**A**		**A**	**A**	**A**	**A**									**N**					
WIRELESS																											
Phase 1				**N**	**N**								**A**		**N**	**N**	**N**	**N**	**N**			**A**					
Phase 2				**A**	**A**								**A**				**A**	**A**					**N**				
VENDOR																											
Phase 1				**N**	**N**	**N**							**N**	**N**					**N**	**N**							
Phase 2				**N**	**A**	**A**							**N**	**A**					**A**		**N**		**N**	**N**	**N**	**N**	**N**

Key

X= Technical Components for the E911 Network

N = New Components for Phase I and Phase II

A = Additional Components for Phase I and Phase II

* Increase in trunks due to increase in call volume not technology.

** Instant recall recorder, logging recorder and printer, power supply are part of PSAP equipment but not affected by Phase I or II.

if it is a new component, or an "A" if it is a projected additional component. New technical components are added to the current E911 network as a direct result of Phase I or Phase II implementation. "Additional" technical components are upgrades or changes to the technical components that are already in place (See Chart A).

B. TECHNICAL COMPONENTS FOR WIRELINE E911 SERVICE

In Chart A, the technical components numbered 1 through 13 are the basic components that were installed in the wireline phone system and PSAPs to build the current E911 network. Appendix E contains definitions for each of these terms.

The wireline technical components perform the following functions:

Send the E911 calls on dedicated trunks from the wireline carriers' central offices to the PSAPs. This separates the emergency from the non-emergency calls.

Route the E911 to the appropriate PSAPs using special equipment, called E911 selective routers. The E911 selective routers, located at the regional wireline company switches, contain software and selective routing information that automatically directs the call to the PSAP that serves the 911 caller's address.[3]

Store and maintain the wireline telephone customers' phone numbers, addresses and emergency response information in the E911 databases. Two E911 databases serve Washington State.[4] Collectively, there are over 2.5 million records in the E911 databases. Each record corresponds to a phone number and is created and maintained whether a 911 call is made or not. The wireline companies update the database daily with information such as customer changed addresses, new phone numbers, etc. PSAPs maintain the street addresses and PSAP boundary changes.[5]

Send the 911 caller's phone number, address and emergency response information from the E911 database to the PSAP. When the call taker answers the phone at the PSAP, a piece of equipment, called the PSAP controller, requests the caller's information from the E911 database. Data circuits and trunks link the E911 database to the PSAP and send the 911 caller's information from the database to the call taker's computer display. Another piece of

[3] The regional wireline switches are large switches that serve multiple counties. For example, the US WEST regional switch located in Spokane manages calls to all or parts of 11 counties. There are 11 regional switches in-state and 2 regional switches in Idaho to serve portions of the Washington-Idaho border.

[4] GTE and SCC, on contract with US WEST, manage the E911 databases.

[5] The E911 database has two parts. One is a database of customer phone numbers and street addresses. The other is a routing database. An emergency service number (ESN) is assigned to a phone number. The ESN corresponds to the PSAP boundaries. Through the routing database, it is known which emergency service responds to a particular phone number. There are two E911 databases. SCC operates one and GTE operates the other. Other wireline companies have business arrangements with SCC or GTE to store their proprietary customer information in the E911 databases. The data in the wireline database is reusable, not easily disrupted, secure, unpublished information that has a high accuracy criteria. The county can audit the E911 database. The E911 database is also subject to WUTC performance standards.

equipment, called the ALI modem, quickly downloads the information to the call taker's computer.

Display the caller's information on the computer screen when the call taker answers the phone. The telephone system and the ANI and ALI hardware and software work together to display the caller's information on the computer screen when the call taker answers the 911 call. The computer aided dispatch (CAD) aids the call taker in handling the call by automating dispatching and record keeping activities.

A technical component common to the E911 network and Phase I and Phase II service is administration. Administration includes the PSAP staff time used for database maintenance and E911 related technical functions, and the technical and legal staff time that the wireline and wireless companies spend on E911 tasks. Administration also includes the E911 portion of the wireline and wireless companies' Network Operations Centers (NOC) which monitor the companies' networks nationwide, 24 hours a day, seven days a week.

C. TECHNICAL COMPONENTS FOR PHASE I

Phase I service sends wireless E911 calls to the appropriate PSAPs with the wireless callers' phone numbers and cell sector locations. Phase I service requires that 12 technical components be added to the E911 network (See Chart A).

The Phase I technical components perform the following functions:

Link the wireless switches to the E911 network with dedicated trunks. This links the wireless network and the E911 network and separates 911 calls from non-emergency calls.

Upgrade the wireless switch to direct emergency calls to the E911 selective routers and send routing directions with the call so the selective router sends the calls to the appropriate PSAP. This requires the installation of new software and a routing database at the wireless switch.

Send the E911 callers' phone numbers and cell sector locations to the wireless E911 database. For the non-call path associated solution (NCAS), new data links from the wireless switch to the private vendor's service control point (SCP), and from the SCP to the E911 database are necessary.[6] For the call path associated (CAS) solution, new data links from the equipment at the wireline switch to the E911 database are necessary. The wireline companies must also add data circuits to the existing E911 database to accommodate the wireless data.

Create a wireless E911 database. The wireline companies add additional record space to the E911 database for wireless calls. These are temporary records that store the information until

[6] The wireless carriers that use private vendors for their Phase I solution chose either SCC or XYPOINT.

it is sent to the PSAP. The space in the wireless database is constantly used for incoming 911 call information.

There is ongoing maintenance for the wireless E911 database. Wireline companies maintain the routing database for the emergency response information. The PSAPs determine and maintain information for routing from a cell sector to a PSAP and perform additions to the database. The wireless carriers and the vendors program database translation into the wireless switches and make changes in cell sector coverage as they re-engineer their networks.[7]

Send information from multiple wireless companies to the appropriate E911 database. The private vendors and the wireline companies add a new mechanism, which interfaces with computer software, to allow a query to multiple databases. This is known as ALI steering. ALI steering allows the private vendor to steer the Phase I information from various wireless carriers to the appropriate E911 database.

There are no new or additional technical components needed to send the wireless 911 caller's information from the E911 database to the PSAP. The wireless caller's information is sent to the PSAP via the existing 911 trunks and circuits that link the E911 database and the PSAP.

The PSAPs do not require new equipment for Phase I service.

D. PROJECTED TECHNICAL COMPONENTS FOR PHASE II

Phase II service sends the E911 caller's location, in terms of latitude and longitude, to the PSAP. Phase II service may require that 22 projected technical components be added to the E911 network, assuming that the wireless carriers choose different technologies. (See Chart A).

The Phase II technical components perform the following functions:

Determine the 911 caller's location in terms of latitude and longitude. Location determination requires the wireless carriers to choose a solution and add the appropriate technology to their networks. The wireless network solutions that are currently known, include Time Difference of Arrival (TDOA) and Angle of Arrival (AOA) technologies. These technologies require the addition of position-determining equipment at cell sites, and location processors at the wireless switches. There is also a network operation console that the wireless company installs to monitor the TDOA system.

The cellular-assisted GPS handset solution requires a GPS receiver to be installed in the wireless handset, equipment to be located at cell sites, and network equipment that computes

[7] Wireless carriers audit the wireless E911 database. Counties do some auditing of cell sectors.

the latitude and longitude. The PSAP must add additional equipment to receive latitude and longitude data.

The autonomous GPS handset solution requires a GPS receiver and processor to be installed in the handset and location determination technology equipment must be added at the PSAP to extract the latitude and longitude data. A voice band modem is also installed at the wireless switch or the E911 selective router to provide data for routing the call based on its location. Then a second voice band modem is installed at the PSAP to provide the latitude and longitude data.

Send additional data for location information to the PSAP along with the caller's phone number and emergency response information. Latitude and longitude information requires additional data be sent to the PSAP. This results in additional components for the Phase I system to handle more data.

Route the call to the proper PSAP. Phase II call routing requires the creation of a new relational PSAP database. A relational PSAP database contains the PSAP boundary maps and emergency service boundaries plotted in latitude and longitude coordinates rather than address ranges. Some vendors who created a relational PSAP database for Phase I may have to update it for Phase II.[8] There are also upgrades to the ALI steering interface, the software at the MSC, and the routing translation at the MSC.

Display the location on the call taker's computer screen. Phase II requires some of the PSAPs to replace their current computer hardware and software at the call taker positions and upgrade the computer aided dispatch (CAD) equipment to display the location data and convert latitude and longitude to usable call response information. An upgrade to the ALI modem is also necessary to increase the data transmittal speed.

Conversion of the latitude and longitude data into useful location information requires accurate maps. Current county and city maps are not accurate enough to do this and have to be GPS corrected for latitude and longitude before they will be adequate. Also the PSAP equipment requires additional technology to display these maps at the call takers positions.

[8] A relational PSAP database may also be used for Phase I. However, it is not essential for Phase I. The King County 911 coordinator develops the necessary Phase I routing with the wireless carrier's engineers without using a relational PSAP database. Private vendors may choose to develop a relational PSAP database as part of their Phase I solution and in preparation for Phase II.